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ONR Summer Internship Program: Summary of Tasks in the Towed Array Exploratory Development Branch (Code 2141)

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Summary of Tasks in the Towed Array Exploratory Development Branch (Code 2141)

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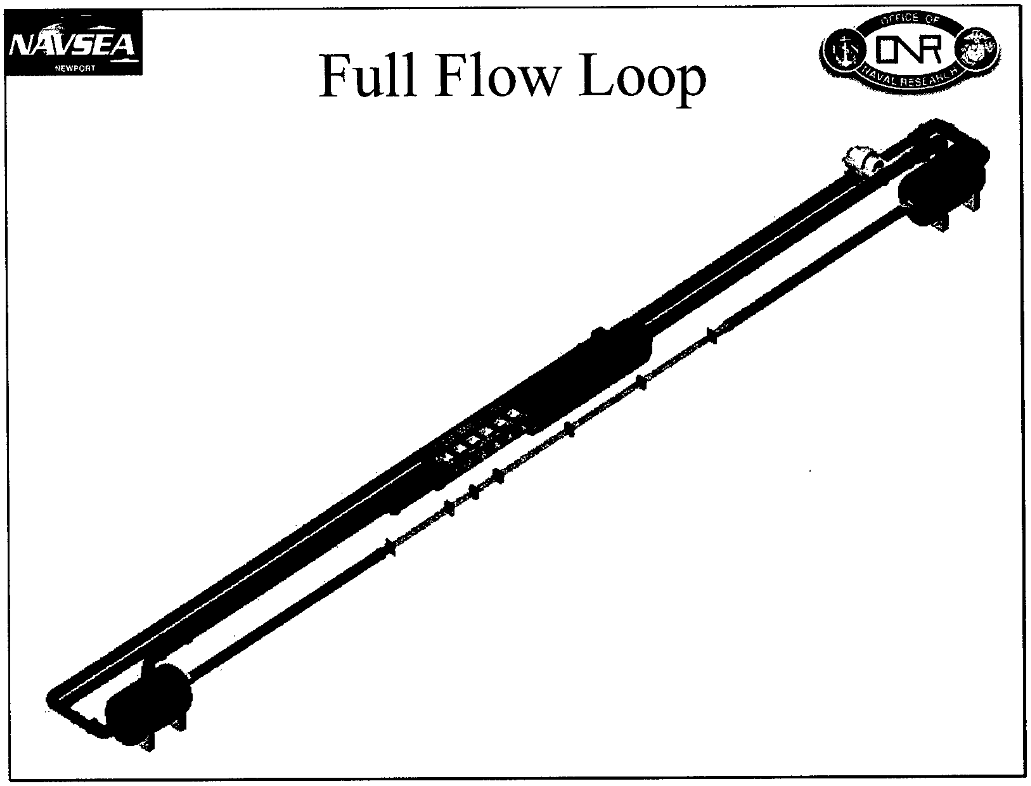
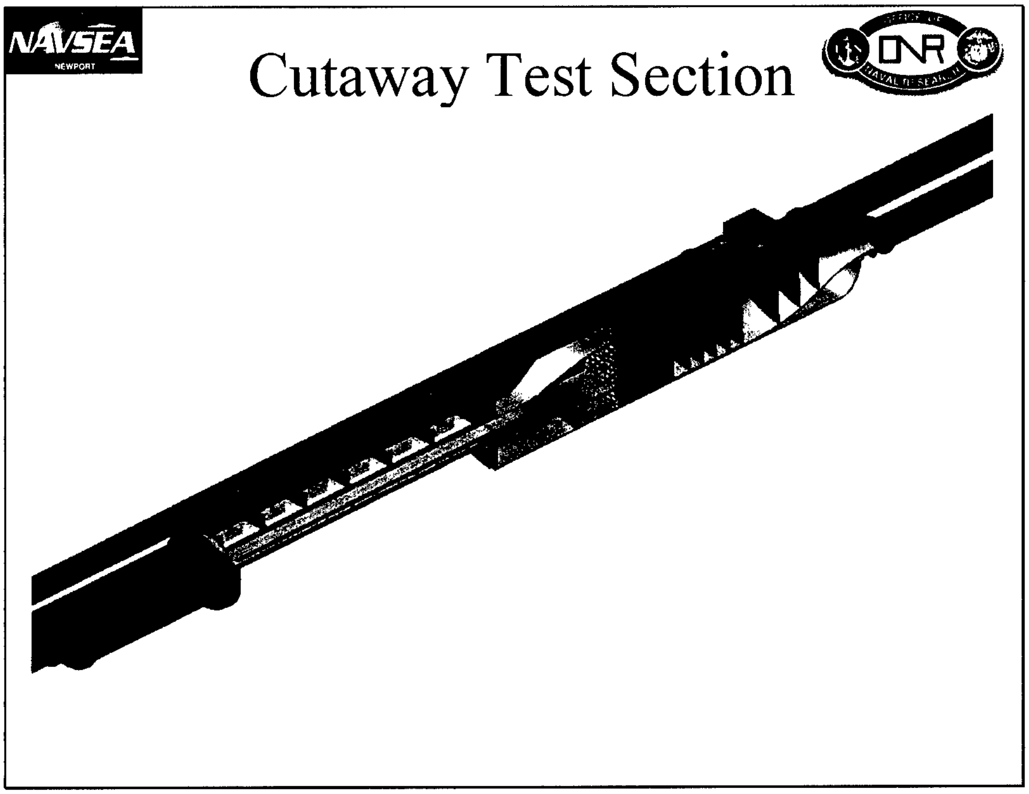
NUWC's QUIET WATER TUNNEL



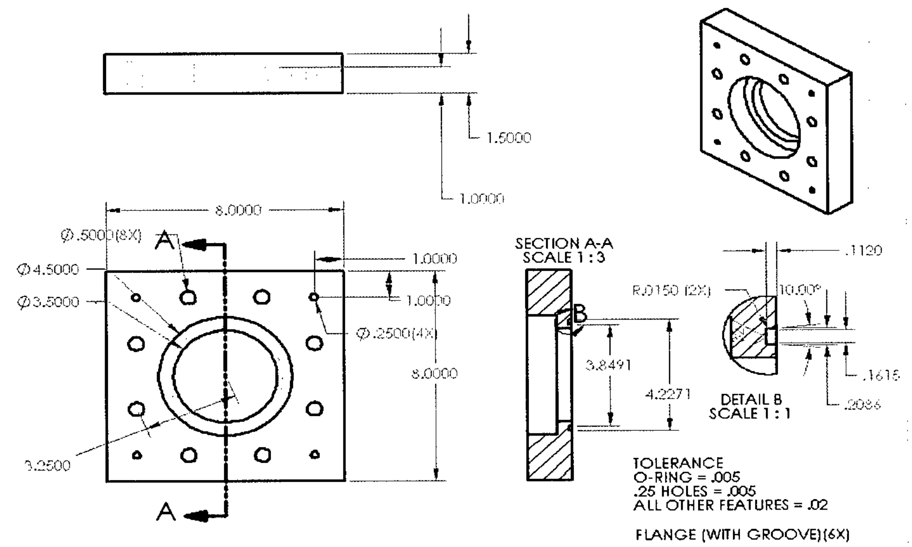
The first project we were assigned was to create a computer model of the Quiet Water Tunnel (QWT) using Solidworks. The pump is visible in the upper right-hand corner, next to the upper plenum chamber. All three plenum chambers are designed to take the swirl and turbulence out of the water. The flow then exits to the middle plenum chamber and rectangular test section, where it is decelerated again before being accelerated into the test section. It then slows and expands in a diffuser flowing through fire hose into the lower plenum chamber. Next, it is split into two return lines to complete the closed loop.

One component not present in the existing water tunnel facility is the circular test section exiting from the horizontal opening in the plenums. We designed the layout and flanges for this section. The circular test section would provide a higher velocity pipe flow due to the narrower cross-sectional area. Also, since it is made of acrylic, it would be transparent for easier visual or laser-based measurements.



The screens and aluminum honeycomb used to straighten the flow are visible in this close-up cutaway view of the test section and middle plenum chamber. Also visible are the viewports along the top of the test section.

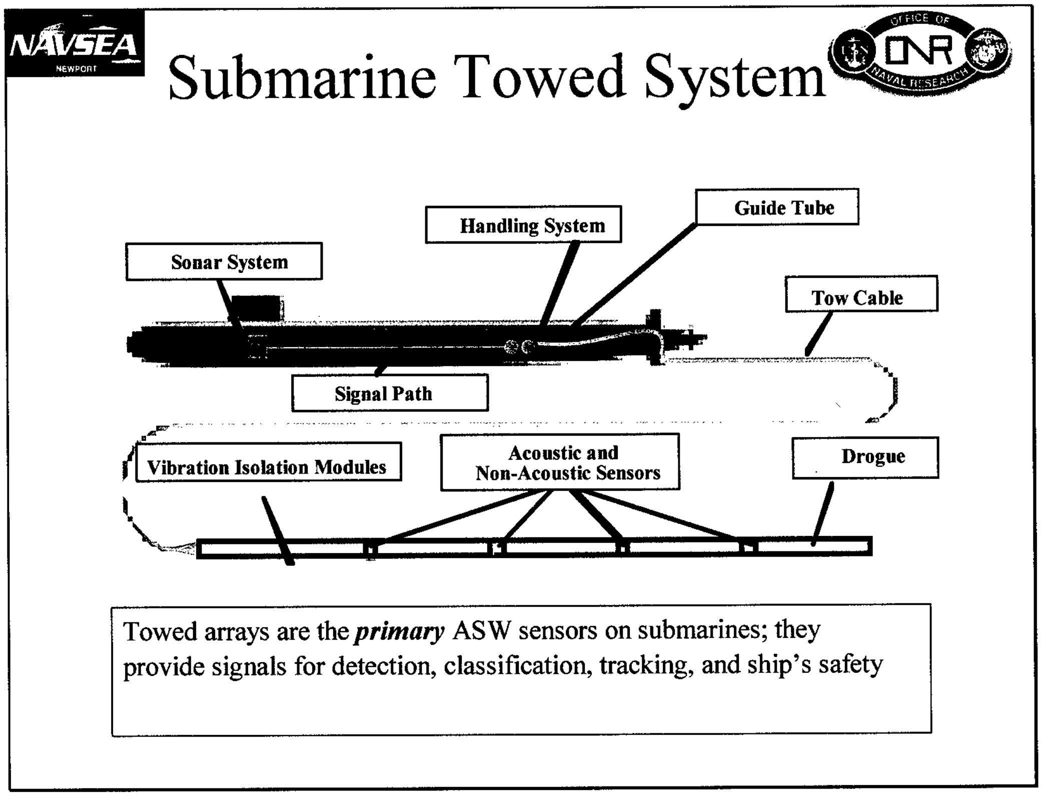
Flange with Groove



This is one of our flange designs for connecting the sections of acrylic pipe together for the circular test section. The pipe will be chemically welded to the flange in the center hole, one flange on each end, and these would be bolted together with an O-ring in between for a tight seal.

TOWED ARRAYS IN TURNS:

Data Analysis and Experiments



A towed array is essentially a hose filled with sensors that is towed behind a submarine or surface ship by a tow cable. One of the benefits of a towed array is that the array is pulled far behind the submarine, which separates the sensors from the noise of the hull. Another benefit is that the array can be longer than the submarine since it is not part of the submarine during operation.

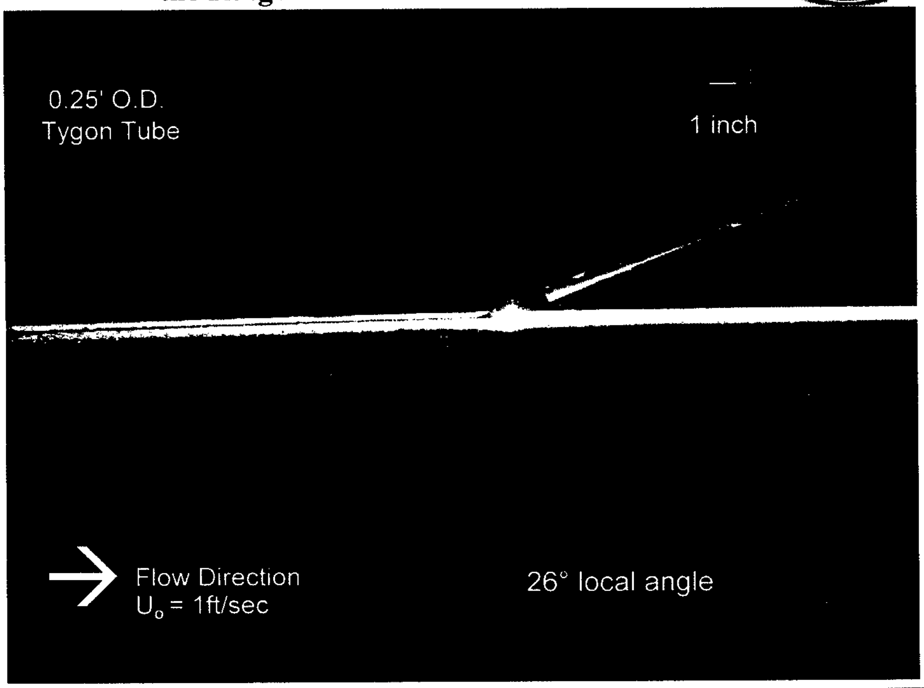
Towed Array Behavior in Turns

- At this point in time, not a lot is known about the way an array follows a ship in turn.
- Some assume a theory called water pulley, which states that the array will exactly follow the path of the ship.
- In order to study this, we were given x and y coordinates of a surface ship and different parts of a towed array at different time steps.
- Plotting these paths showed that the array followed a different path than the ship, demonstrating that these data does not support the water pulley theory.

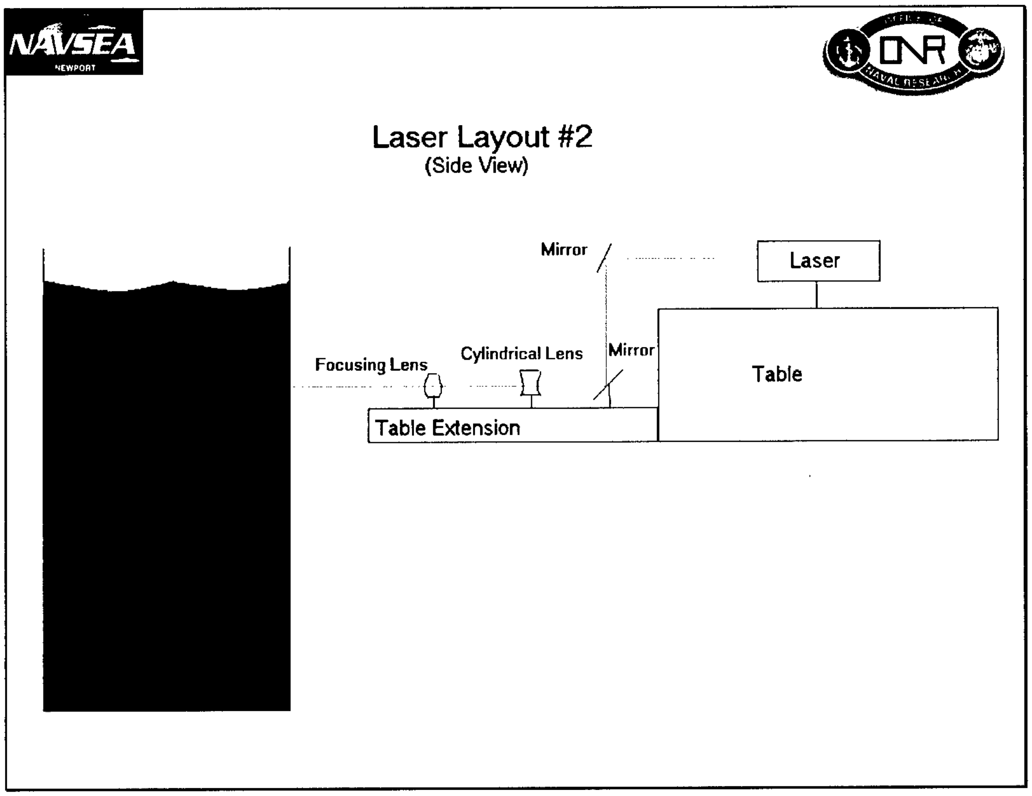
Towed Array Behavior in Turns (Cont'd)

- Another assumption of the water pulley theory is that the front and back of the array follow each other.
- In order to test this theory, the paths of the front and back of the array were also traced. Comparison of the data further demonstrated that water pulley does not apply.
- Local angles were determined for each time step of the turn using Matlab, and an estimate of the location of boundary layer separation was made. Knowledge of this location is important because the array experiences an increase in noise after separation occurs.

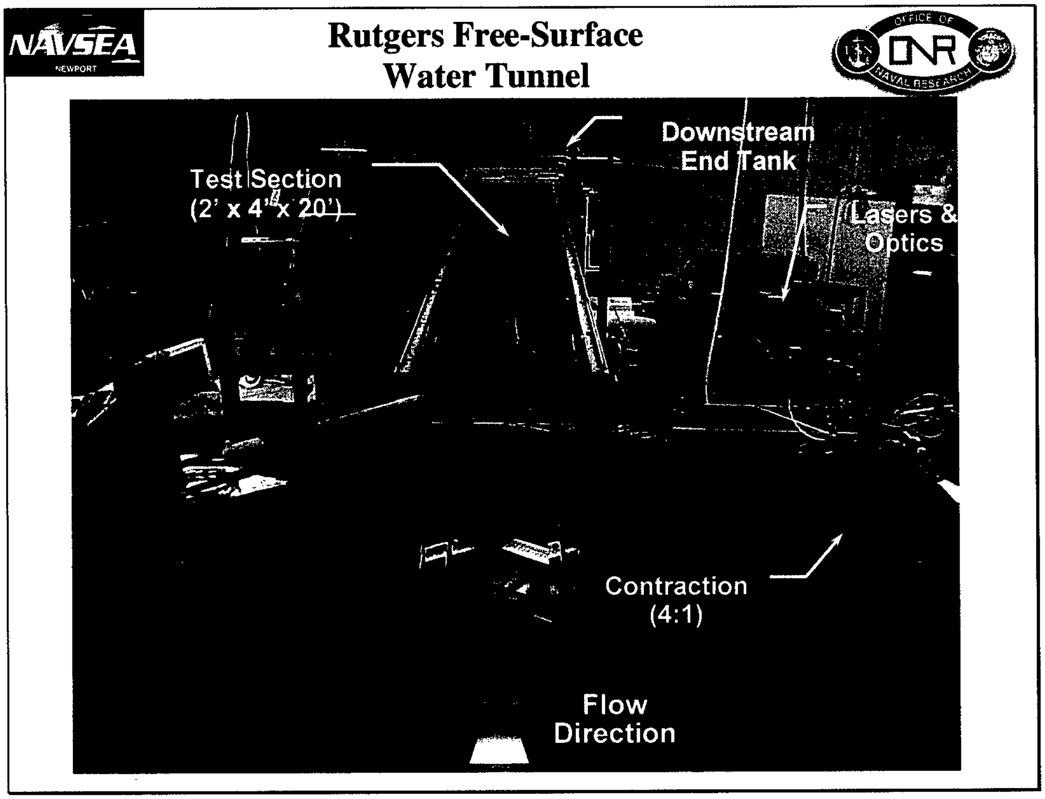
Photograph of a Towed Array In-Turn Model in the Rutgers Free-Surface Water Tunnel



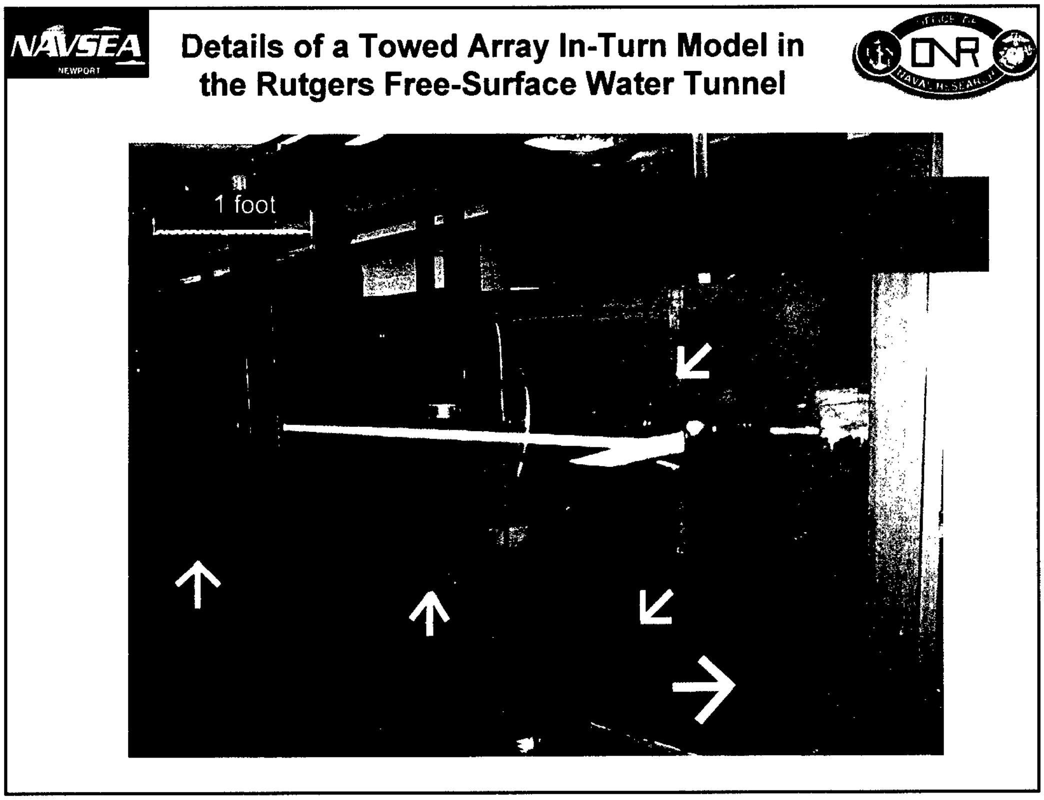
The angles and shapes found in actual towed array data were then taken to Rutgers University and imitated in the Free-Surface Water Tunnel facility. Tygon tube was used as a model of the array, and a laser sheet was shot across the tube in order to perform digital particle image velocimetry (DPIV) measurements.



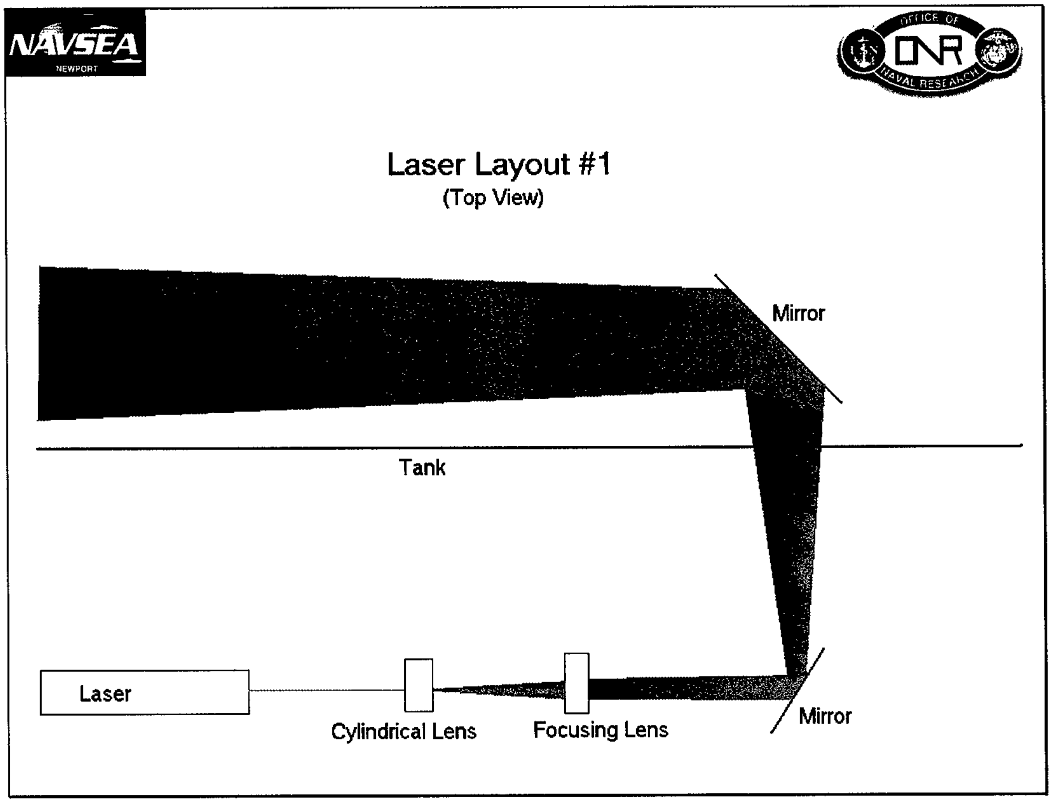
The lasers and optics had to be adjusted according to the angle of the tube in order to get a flat laser sheet to penetrate the tank at the location of interest.



This is the layout of the water tunnel in which the experiment was conducted.

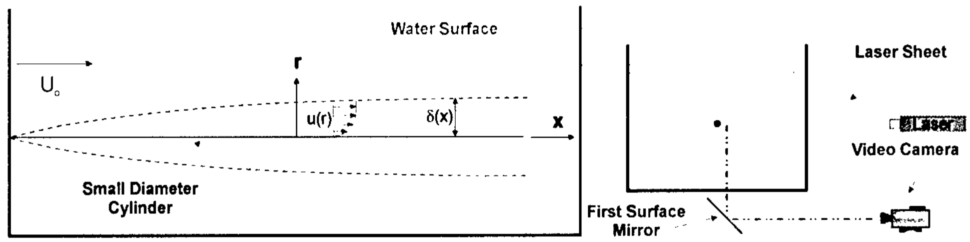


The Tygon tube was set up parallel to the flow along the centerline of the tank. Fishing line was tied to the end of the tank to hold the straight portion of the Tygon tube in place (the piece identified in the photo). Another piece of fishing line was used to hold the end of the Tygon tube above the waterline, creating a curved section.



The focusing lenses, cylindrical lenses, and mirrors had to be adjusted in order to obtain a flat sheet of laser light.

Approach - DPIV Measurements



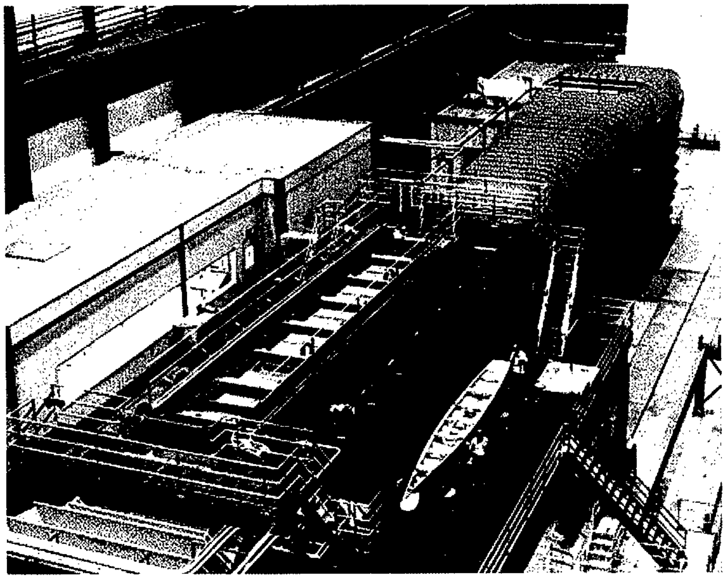
- Experiments conducted in the Rutgers University Free-Surface Water Channel
- Two-dimensional instantaneous velocity fields obtained using digital particle image velocimetry (DPIV)

Small glass particles were added to the flow and the lights were turned down. The laser sheet illuminated these particles while a digital camera acquired pictures at the same speed as the laser pulsed. The camera picked up consecutive pictures of the particles in the flowfield. These pictures were then put into a computer program to correlate one particle to another. As a result of these correlations, the distances of the particles were known. The time between each picture was also known; therefore, two-dimensional velocity fields were obtained. These are the basic steps of DPIV measurement testing. The purpose of conducting DPIV testing in this experiment was to find the effects that boundary layer growth and separation had on the velocity fields.

MULTILINE TOWED ARRAY (MLTA)

Aperture Generation System Testing

Large Cavitation Channel



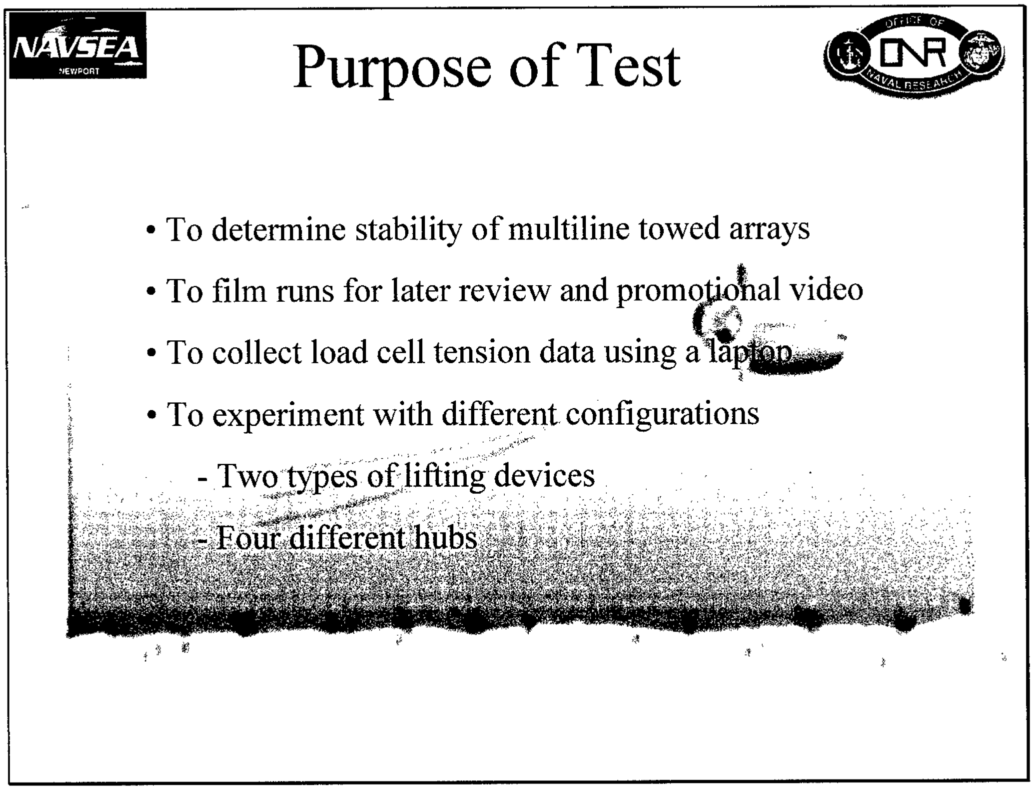
The Large Cavitation Channel (LCC) facility is located at NAVSEA, Carderock Division, Memphis, TN, and was the location of the MLTA experiment. You are looking at the upper part of the LCC; the dark part is the test section, and the blue parts are the nozzle and the diffuser.

Operating Specifications

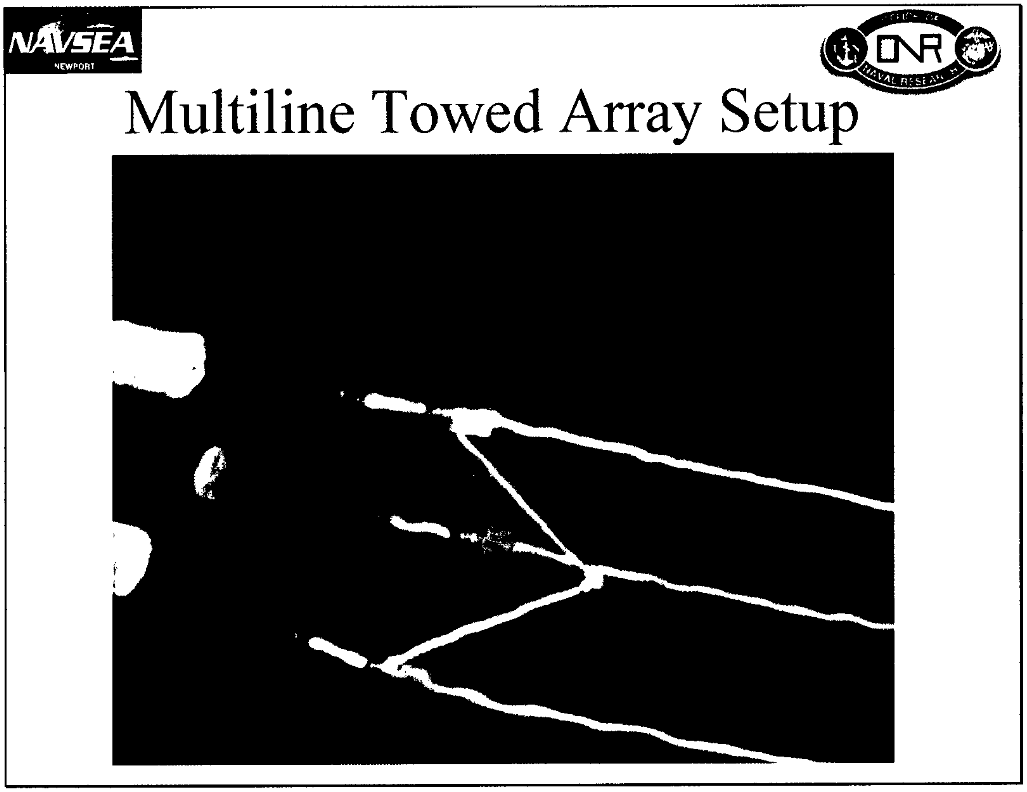
- **Test Section Pressure: 3.5 to 414 kPa (0.03 to 4 atmospheres, 0.5 to 60 psia)**
- **Test Section Velocity: 2.6 to 18 m/s**

  (5 to 35 knots, 8.5 to 59 ft/s)
- **Test Section Size: 3 x 3 m (10 x 10 ft) in cross section and 13 m (43 ft) in length**
- **Air Content: 10% to 100% saturation**

These are some general specifications on the LCC. Only the flow speed was varied in our experiment; however, controlling the pressure and air content does enhance the capabilities of the facility. To avoid stressing our equipment too much, the speed range for these tests was 0 to 26 knots.

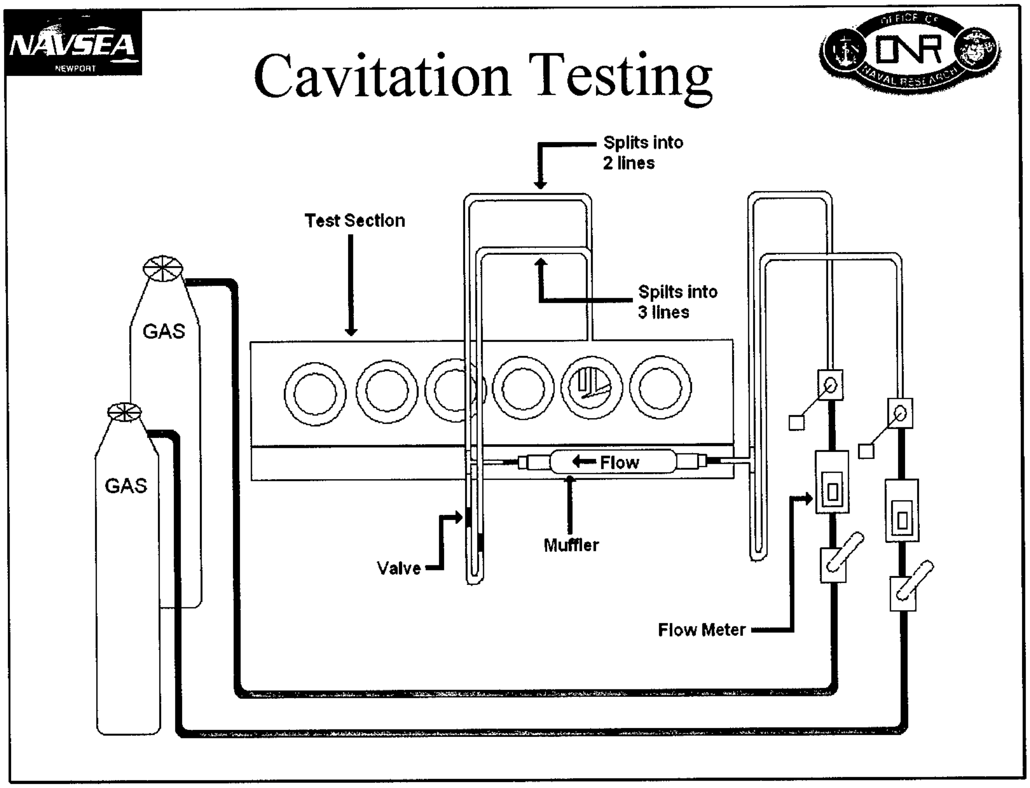


The purpose of our test was to make observations of the stability of a device intended to separate three ropes simulating towed array lines. For a multiline towed array to work properly, the position of every element in the array has to be known. For that to happen, the MLTA cannot be rotating or oscillating. It must remain stable and upright in order to provide useful tracking data. We were testing a device that would attempt to ensure this stability. During the test, we filmed all of the runs for later review and to follow up on-site observations. We collected tension data through a load cell and recorded it onto a laptop. This was to see what kind of stresses our device was experiencing. We tried many different configurations. Two of the main features we varied were the types of lifting devices used and the type of hub our device used.

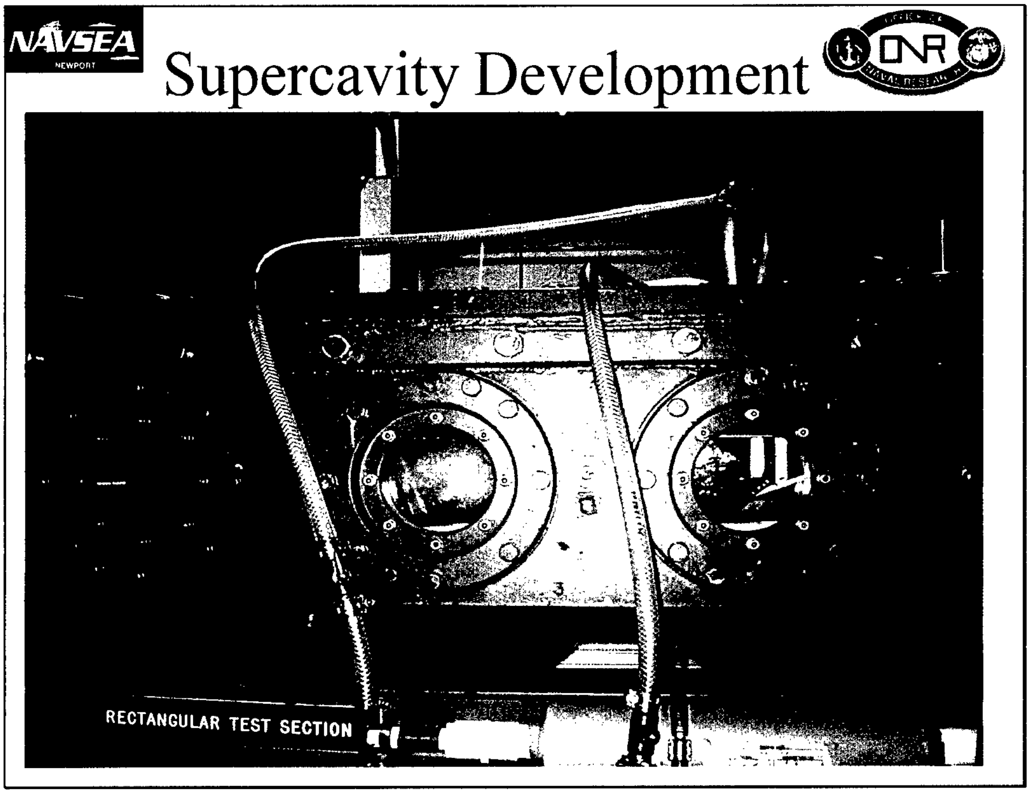


This is the MLTA setup. You can see the hub in the center. It resembles a tripod with legs that can hinge in toward the center and fold into a rod. At the end of each leg is the wing used to generate a radial force outward and to open the apparatus. On the left side of the screen the rope drogues are visible. Since an entire array did not fit into the 43-foot test section of the LCC, we simulated it using these 6-foot-long rope drogues. All of the components were brightly colored in order to stand out on film.

CAVITATION EXPERIMENTS



The last experiment we participated in was a cavitation study relevant to the supercavitating torpedo concept. The purpose of supercavitation is to move a torpedo or other object at such a high rate of speed that the water surrounding the object turns to gas due to the low pressure. This would provide a dramatic decrease in drag – therefore, a very large velocity gain. To help the formation of the cavity, gas can be injected at lower speeds. The purpose of this test was to investigate cavitation noise in a quiet water tunnel. A wedge was mounted in the quiet water tunnel, and we attempted to simulate the conditions of supercavitation using gas injection and the wedge. You can see the gas bottles on the left – the gas was fed past cutoff valves and into flowmeters so that the precise injection rate could be recorded. The gas then flowed past thermal sensors to record its temperature. The gas was then pushed through a muffler to dampen any noise generated in the tanks, regulators, or flowmeters. The gas then went through another set of valves, to keep water from backing up in the muffler, before finally being split into five lines and being fed into the five injection ports mounted on the wedge.



This picture shows an example of the experimental results. You can clearly see the trail of gas from the cavitation, as well as the hoses we arranged to deliver the gas to the wedge. As the water flows past the wedge, the reduction in flow area causes it to accelerate to approximately four times its normal speed in the beginning of the test section. As it rounds the corner of the wedge, the five gas ports inject CO_2 into the area directly behind the wedge. Baseline measurements were taken using eight hydrophones mounted upstream of the wedge. Measurements of the accelerating flow and structure noise were taken with three hydrophones mounted on the wedge face, and an array of 48 hydrophones measured the sound profile of the cavity itself. An interesting result was that the noise increased with speed up to a point, but when full cavitation developed, the noise level rapidly dropped off. Further investigation of this phenomenon is planned.

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